



Antares: A Deep-Sea 0.1 km² Neutrino Telescope

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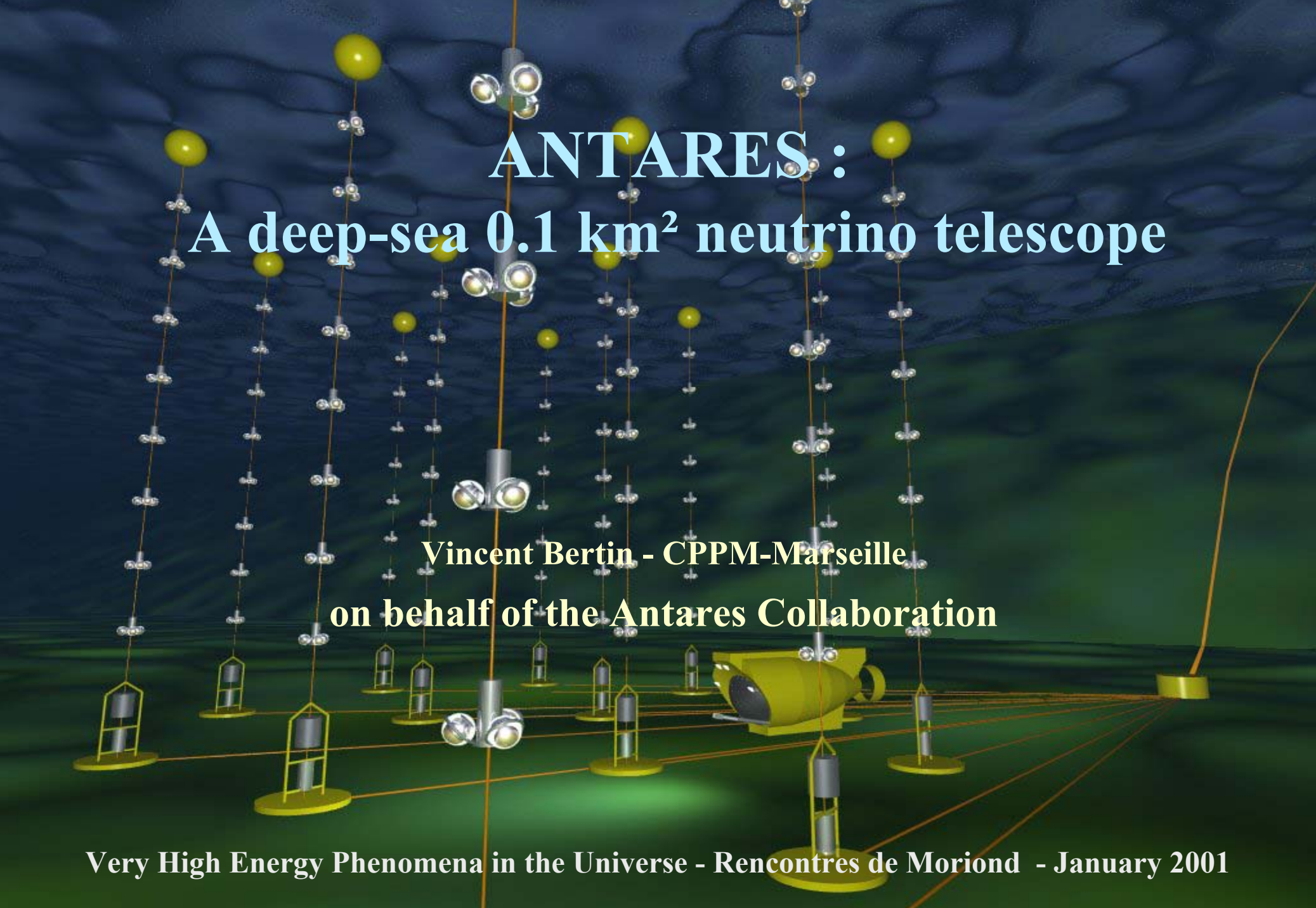
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A 3D computer-generated illustration of the ANTARES neutrino telescope. The scene is set in a deep-sea environment with a dark blue, wavy background representing the water surface. The telescope consists of numerous vertical strings of optical modules (OMs) suspended from a central point. Each string is connected to a yellow buoy on the surface. The OMs are depicted as small, cylindrical devices with multiple lenses. Some strings have larger, more complex structures at the top, possibly representing the main support or communication systems. The overall layout is a grid-like pattern of strings, creating a large volume for detecting neutrinos.

ANTARES :

A deep-sea 0.1 km² neutrino telescope

Vincent Bertin - CPPM-Marseille
on behalf of the Antares Collaboration

Very High Energy Phenomena in the Universe - Rencontres de Moriond - January 2001

The ANTARES Collaboration



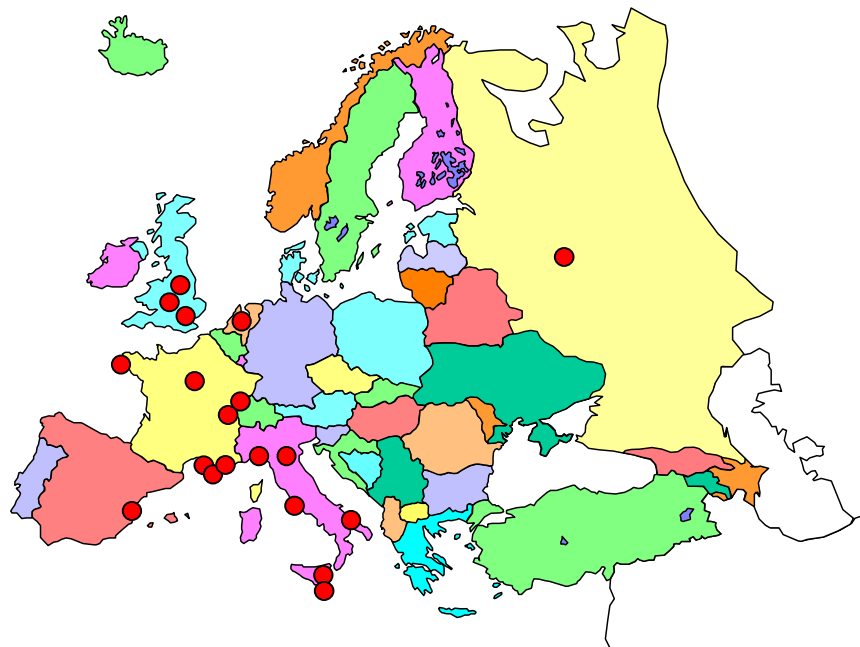
- ❖ CPPM, Marseille (IN2P3)
- ❖ DSM/DAPNIA, Saclay (CEA)
- ❖ IReS, Strasbourg
- ❖ Univ. of H.-A., Mulhouse
- ❖ C.O.M. Marseille
- ❖ IFREMER, Marseille/Brest
- ❖ IGRAP (INSU), Provence



- ❖ University of Bari
- ❖ University of Bologna
- ❖ University of Catania
- ❖ LNS – Catania
- ❖ University of Rome
- ❖ University of Genova



- ❖ NIKHEF, Amsterdam



- ❖ University of Oxford
- ❖ University of Sheffield



- ❖ ITEP, Moscow



- ❖ IFIC, Valencia

Detection Principle

Lattice of Photomultipliers : “Optical Modules”

Muon track direction from arrival time of light

Neutrino direction: $\bar{\Delta} (\theta_\nu - \theta_\mu) \approx 0.7^\circ / E^{0.6}(\text{TeV})$

Muon energy from energy loss and range

Cherenkov
light cone

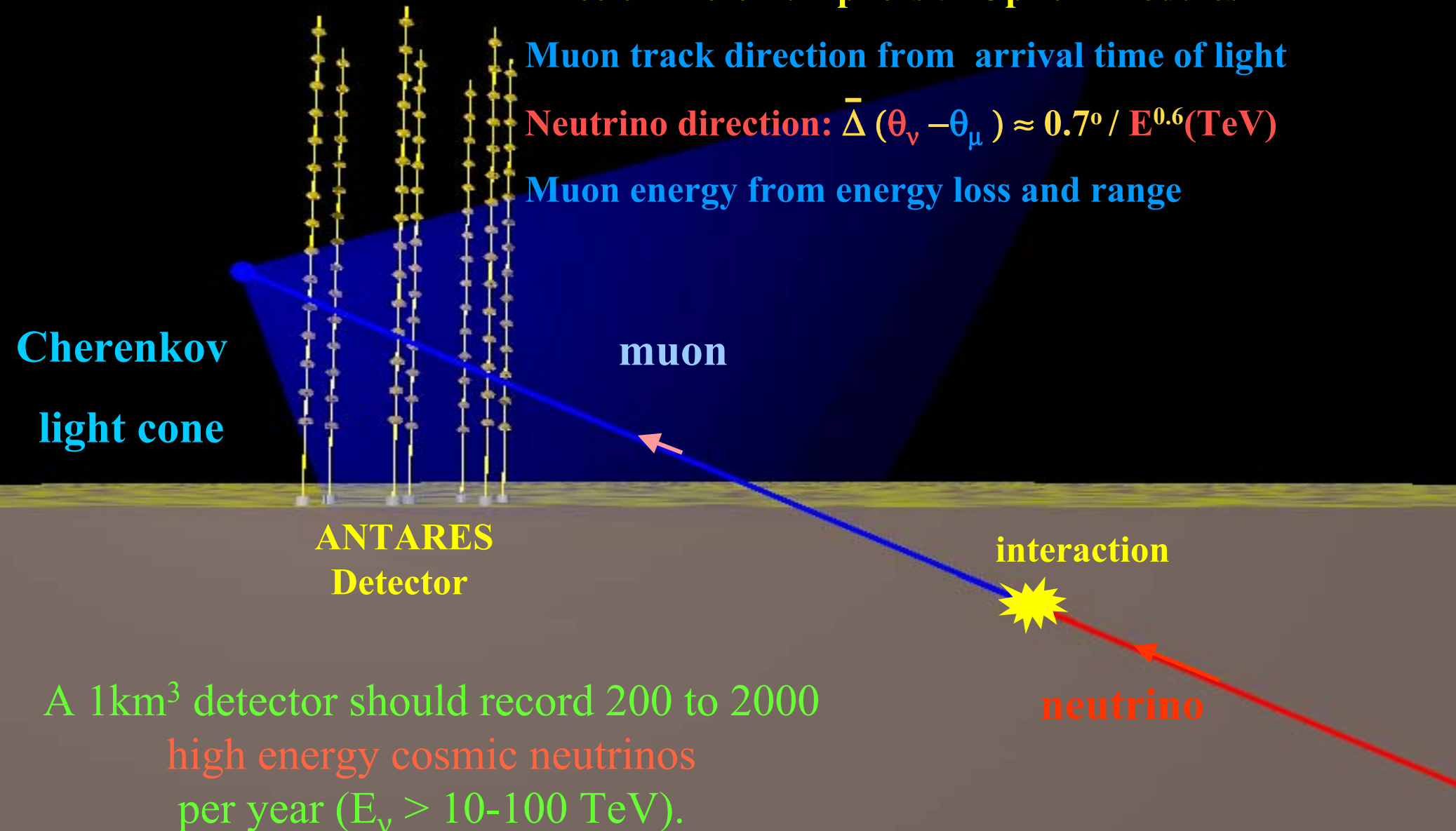
muon

ANTARES
Detector

interaction

neutrino

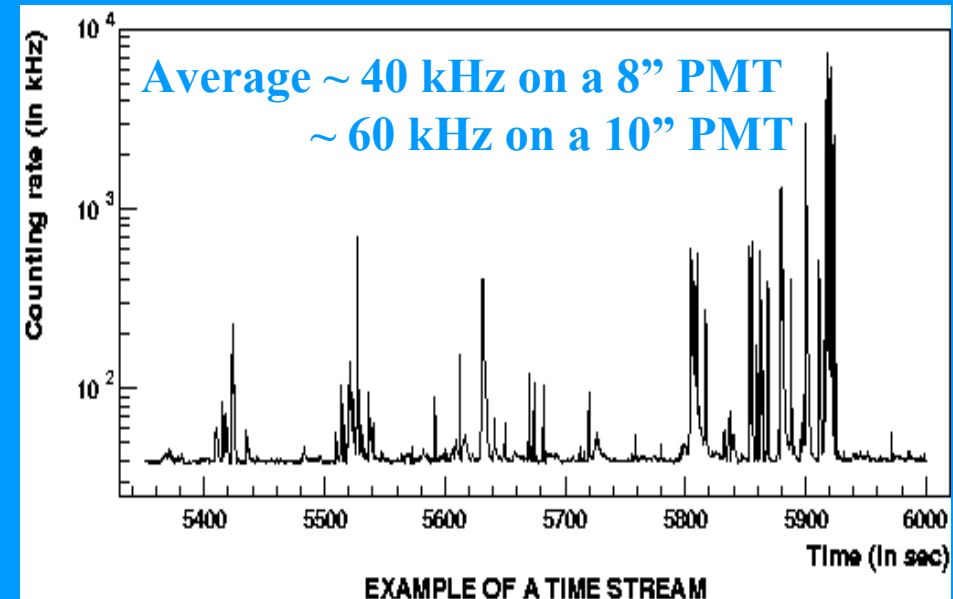
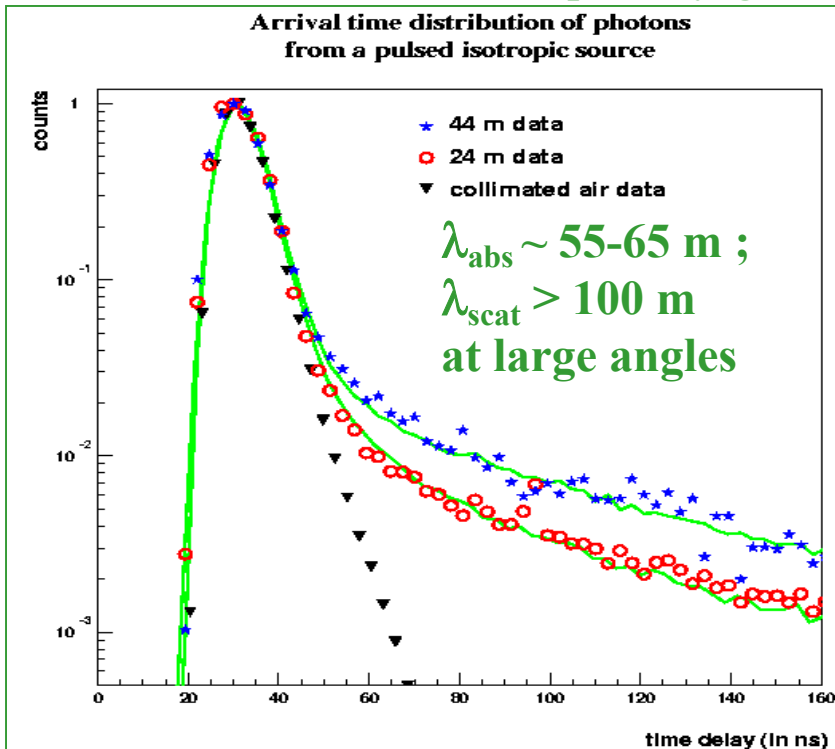
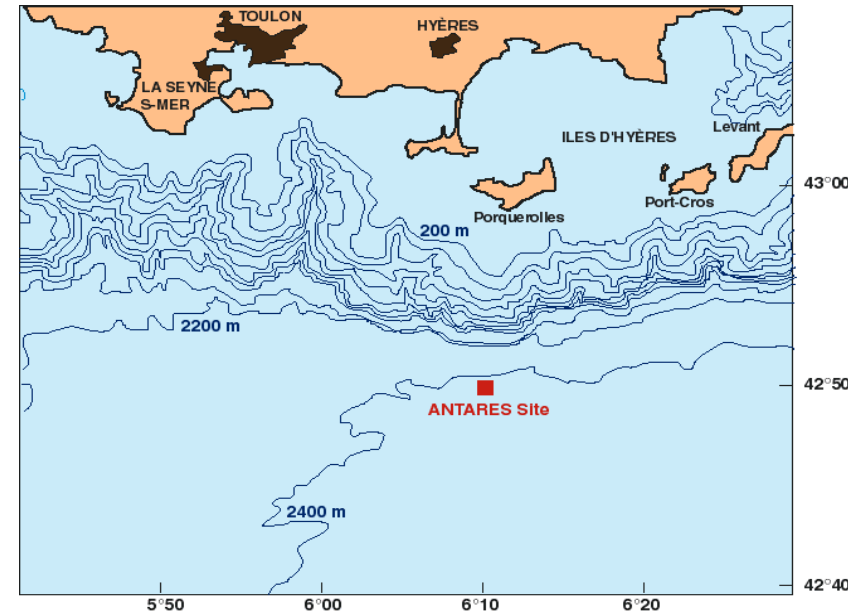
A 1km³ detector should record 200 to 2000
high energy cosmic neutrinos
per year ($E_\nu > 10\text{-}100 \text{ TeV}$).



Phase I : Water properties measurements

■ Perform precise measurements of crucial environmental parameters :

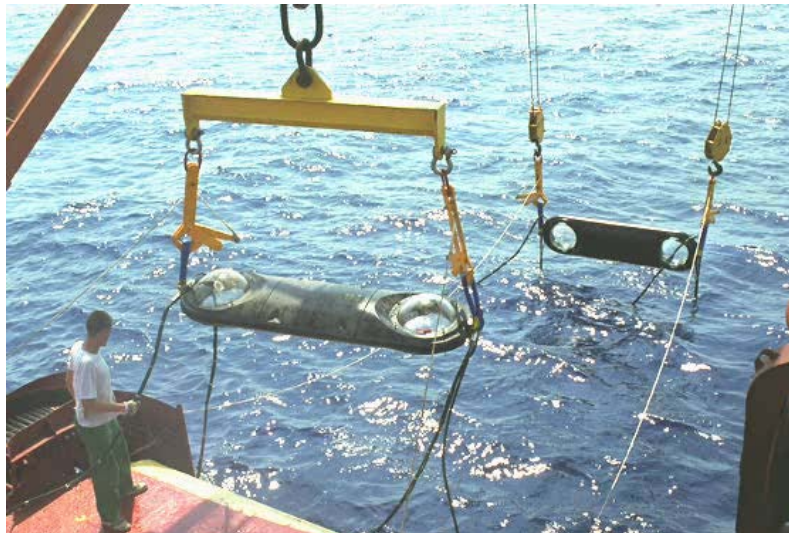
- ◆ In situ measurements on Antares site (2400 m depth off French Mediterranean coast)
- ◆ Long term measurements of optical background (^{40}K decays, bioluminescence) and biofouling of Optical Modules
- ◆ Measurement of water transparency @ 466 nm :



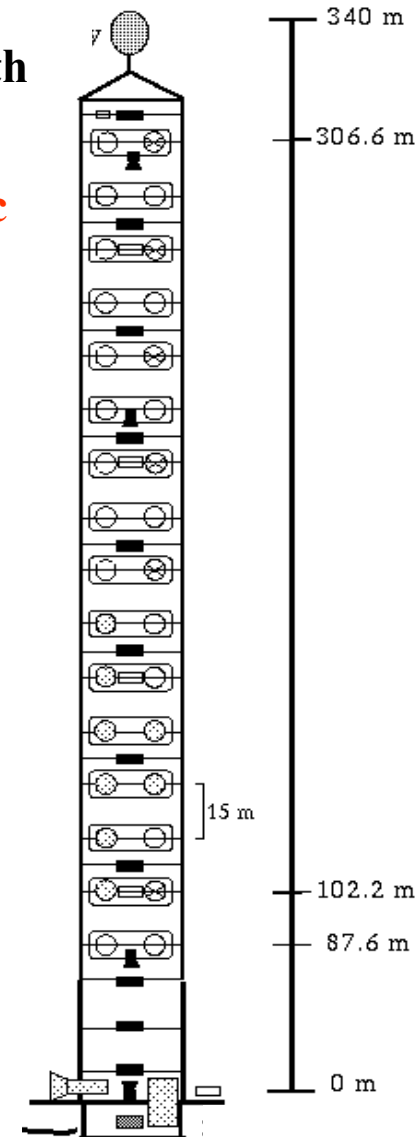
ANTARES Phase I : Demonstrator

- First line of 350m high equipped with 16 pairs of Optical Modules
 - ◆ Summer 98 : successful deployment test at 2300m depth performed with Dynamical Positioning ship
 - ◆ December 99-June 00 : demonstrator equipped with 7 PMTs + acoustic positioning system linked to shore station by electro-optical cable

NAUTILE



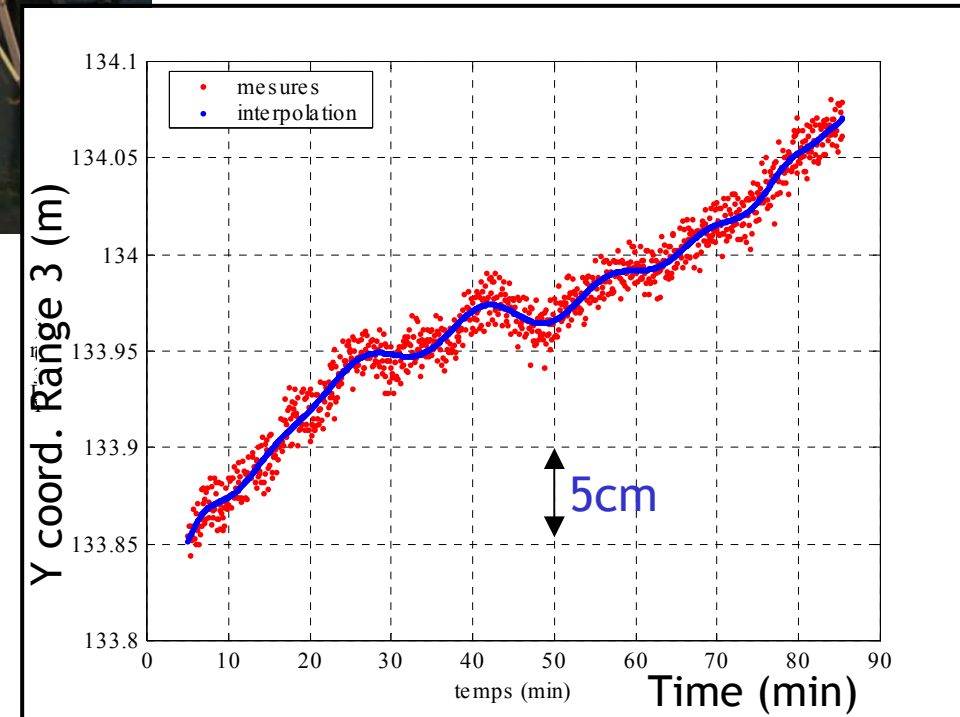
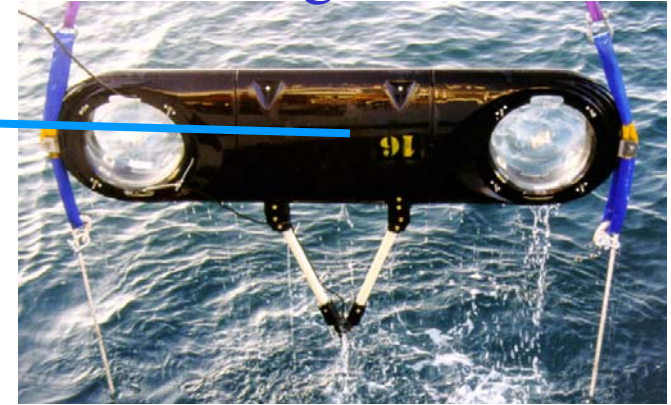
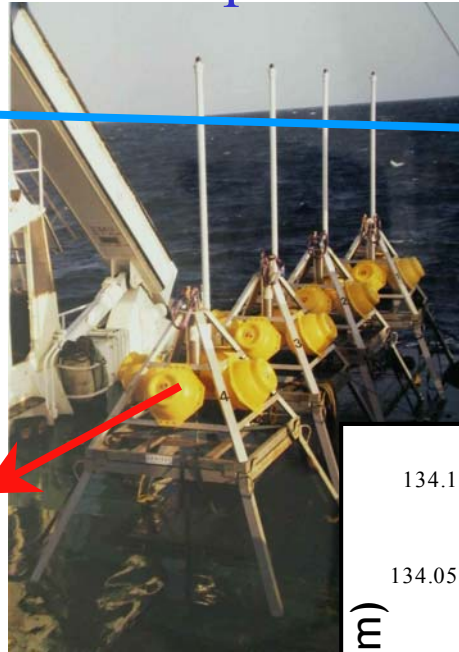
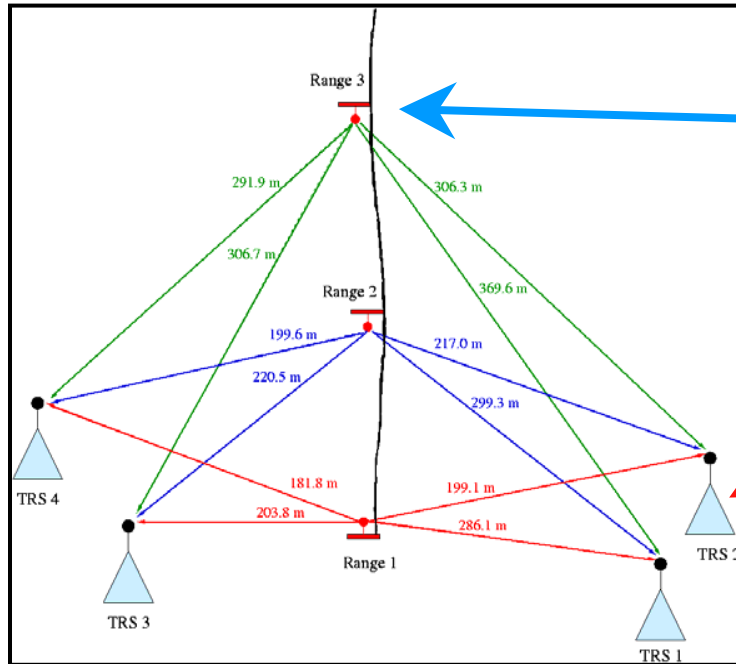
- December 98 : successful undersea electrical connection test of detector anchor performed at 2400m depth by IFREMER submarine vehicle *Nautilie*



Acoustic positioning system

4 transponders

3 rangemeters

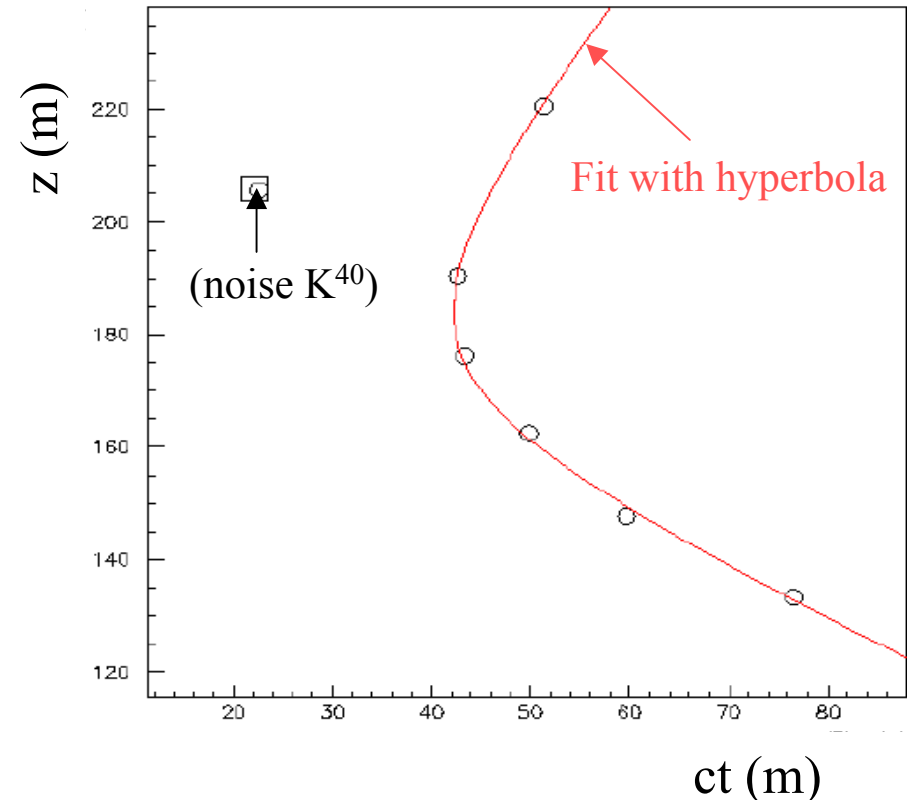
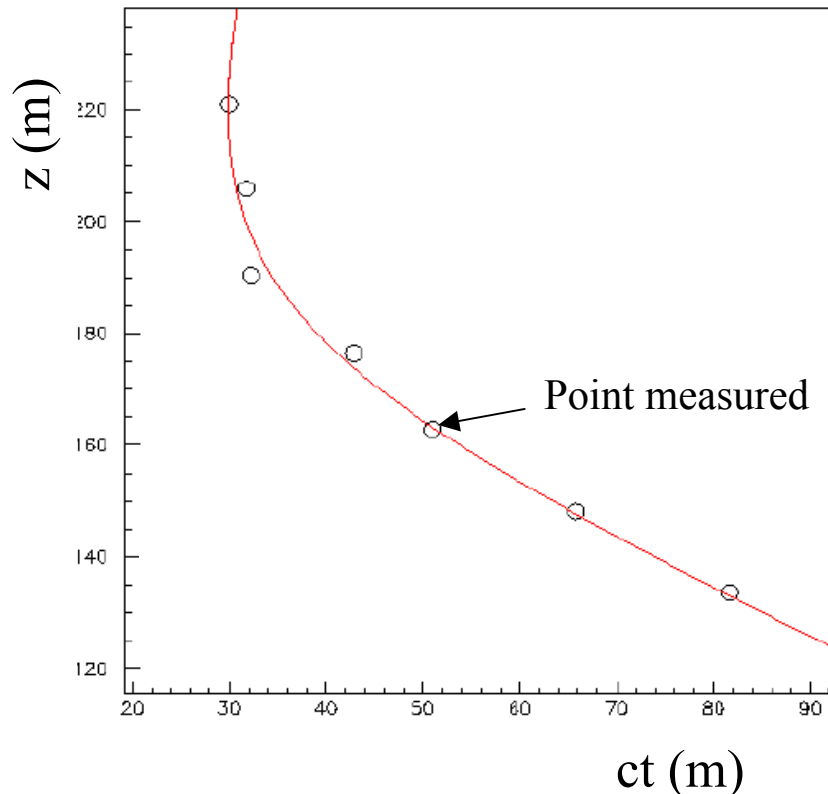


Devices	Accuracy (σ)
Inter-rangemeter	~ 1 cm
Inter-transponder	~ 1 cm
Rang.-Transpond.	≤ 3 cm

Triangulation allows ≤ 5 cm accuracy

Reconstruction of Atmospheric Muons

- More than 5×10^4 coincidences in all 7 PMTs have been recorded.
- Polar angle of down-going muons deduced from depth vs. time pattern.
- Hyperbolic fit (including multimuons).
- ^{40}K filtered out by the reconstruction software (see boxed hit in example).

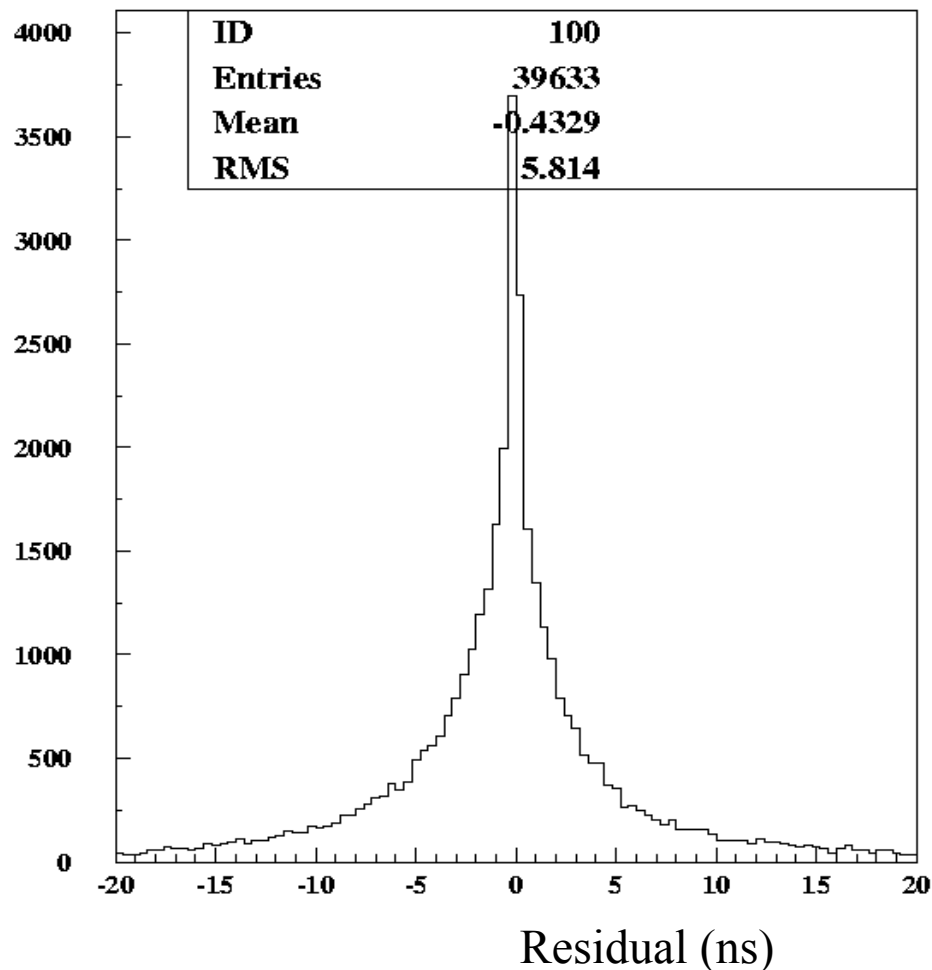


Reconstruction of Atmospheric Muons

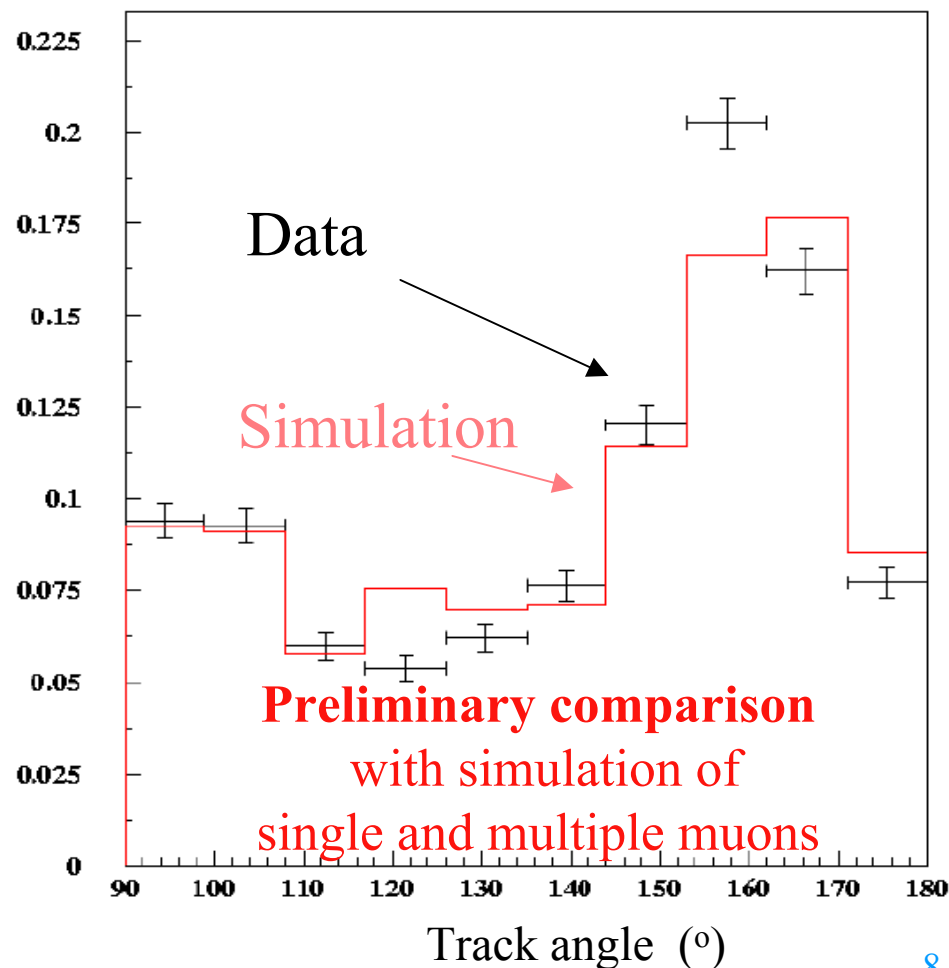
Over 50k 7-fold coincidences recorded

➡ more than **1350 reconstructed events per day**

$\Delta(\text{fit-point})$ in ns



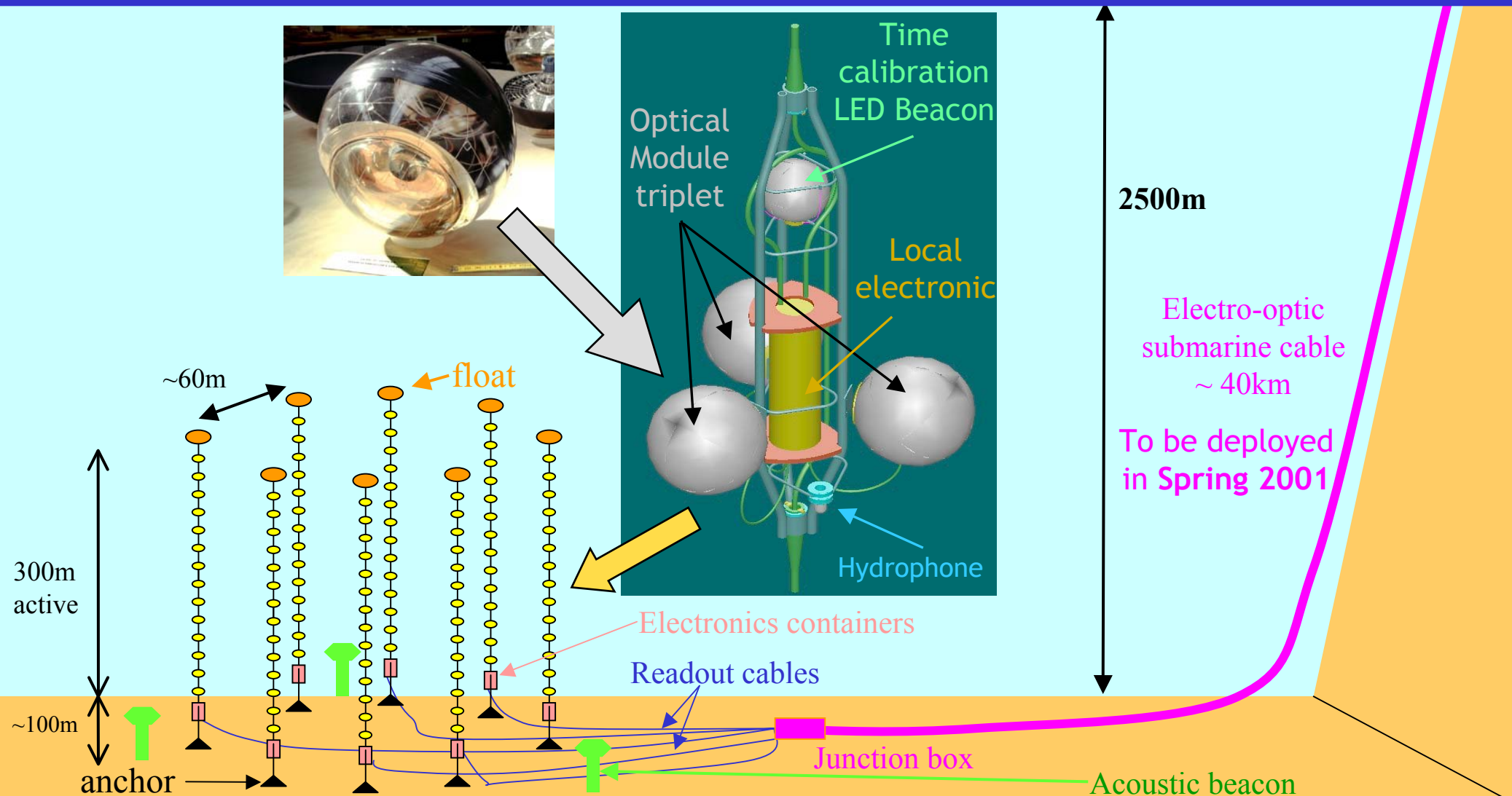
Angular Distribution



ANTARES Phase II : 0.1 km² Detector

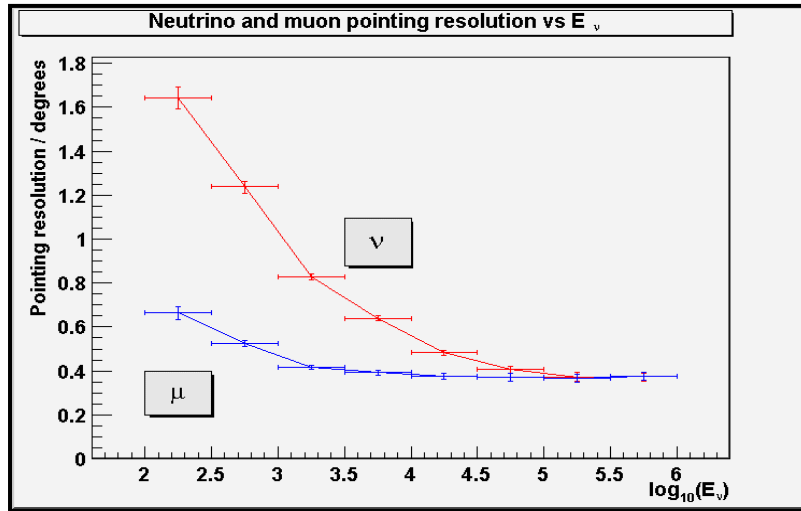
10 strings : 900 PMTs in total
Detector to be deployed at ANTARES site by 2002 - 2004

Shore station



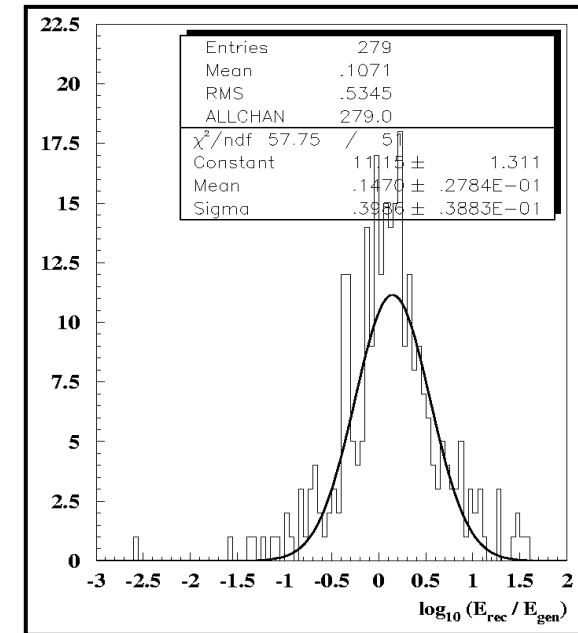
0.1 km² Detector : Expected performance

Angular resolution



- ❖ Including effects of reconstruction and selection, PMT TTS, positioning, timing calibration accuracy and scattering.
- ❖ Below ~ 10 TeV angular error is dominated by ν - μ physical angle.
- ❖ Above ~ 10 TeV angular accuracy is better than 0.4° (reconstruction error).

Energy resolution

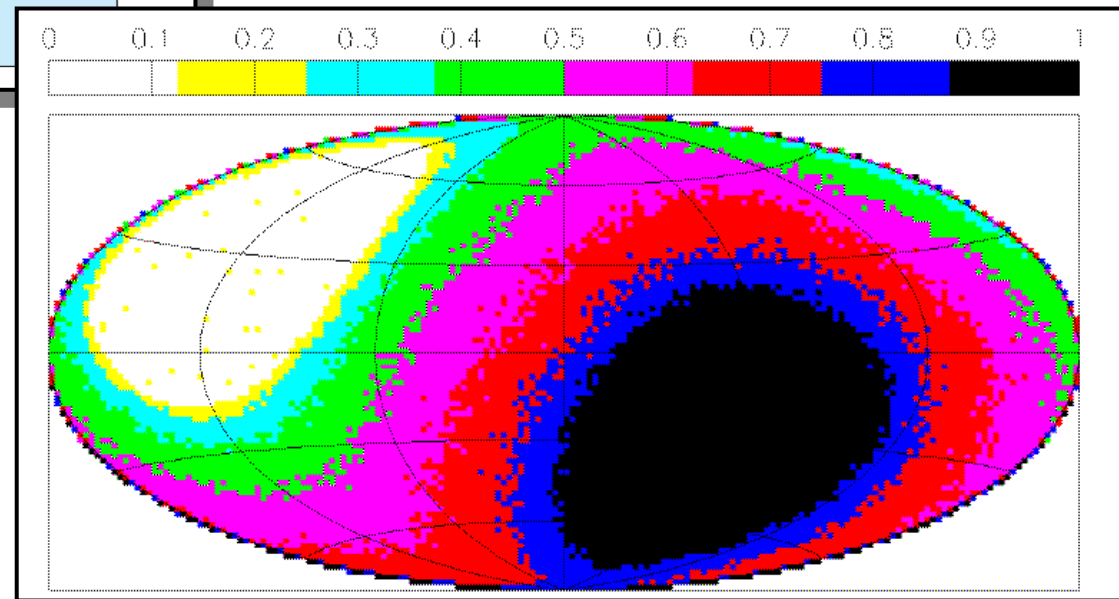


- ❖ $\sigma_E / E \approx 3$ ($E > 1$ TeV)
- ❖ Below $E \sim 100$ GeV energy estimation via muon range measurement.

ANTARES 0.1 km² Detector Site

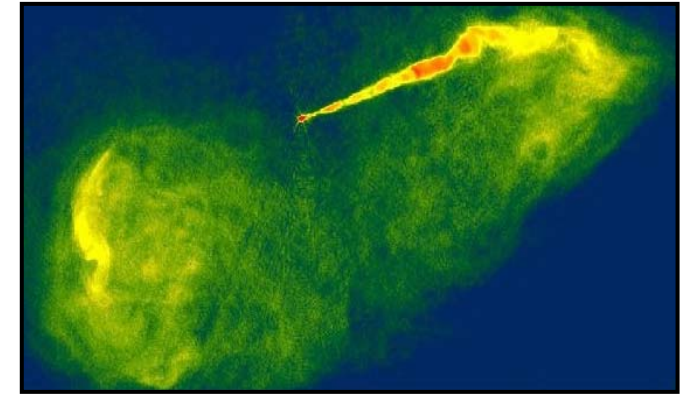
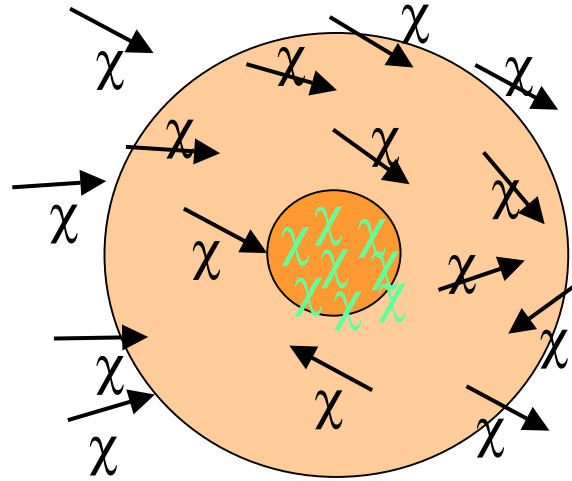
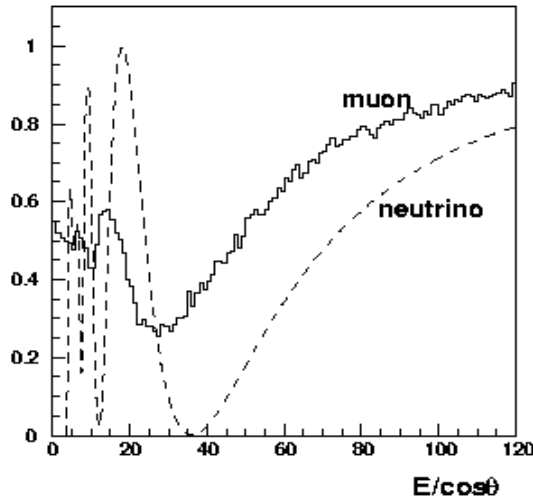
- ❖ 40 km SE of Toulon, Southern France (42° 50' N, 6° 10' E)
- ❖ Shore base at La Seyne-sur-Mer (excellent infrastructure)
- ❖ 2400 m below sea level

- ❖ 3.5π sr of the sky is covered
- ❖ 0.5π sr overlap with Amanda
- ❖ Galactic Centre surveyed



Scientific Programme

Energy →



Low energy

- **Neutrino oscillations** via the modification in the energy spectrum due to **observation of the first oscillation minimum**

Medium Energy

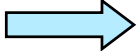
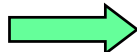
- **Search for neutralinos** via their **self-annihilation** to products containing **neutrinos at the centre of the Earth, Sun and Galaxy**

High energy

- **Observation of neutrinos from (extra-)galactic sources** such as **GRB, AGN, Supernovae remnants, molecular clouds, etc.**

Conclusions

ANTARES has made excellent progress over the past 4 years :

- ◆ Site environmental characterisation  **OK**
- ◆ Tests of marine technologies  **under control**
- ◆ Deployment and operation of Demonstrator String
- ◆ First down-going muons reconstructed
- ◆ Expanding Collaboration

ANTARES is well engaged in Phase II of its programme
by the design, the installation and the running
of a 10-strings 0.1 km² detector in 2002-2004

**Major step forward towards a km-scale
neutrino telescope in the Mediterranean Sea**